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Polyfurfuryl based Polymer Concrete

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Abstract - *Portland cement is used for making mortar and concrete which has been a popular construction material in the world for the past century or more. However, some trouble of cement mortar and concrete such as low tensile strength, low chemical resistance, large drying shrinkage, and delayed hardening. To minimize these troubles, many attempts to use polymers have been made. One such attempt is use of polymer as the binder in concrete, which is made by the innovating ordinary cement mortar or concrete with polymer additives such as water-soluble polymers, liquid resins, latexes, redispersible polymer powders and monomers.*

Objective of this project was to use polyfurfuryl alcohol (PFA) Resin; it is a biodegradable resin, which heals from furfuryl alcohol (FA) to form a thermoset polymer. The uniqueness of this work lies in modifying the compressive strength, flexural strength by using PFA resin which is relatively newer material used as polymer concrete. The polymer concrete is comprises about 40 to about 70% by weight coarse aggregate, about 20 to about 55% by weight fine aggregate (sand), about 2 to about 15% silica flour and about 8 to about 12% furan resin formed by the in situ polymerization of FA with aid of an acid catalyst.

***Key Words*: Polymer; binder; additives; PFA resin; polymer concrete; strength**

1. INTRODUCTION

Polymer concrete is monomers that are polymerized in place in presence of different components. In place polymerization takes place by catalysts, heat, or radiation. Monomer once polymerized will be used because the binder component which doesn't need water to set or harden. Polymer concrete contains polymeric binder, aggregate and hardener. The interactions among these components rely entirely on the chemical and physical reactions. Since late 70s, to replace ancient or traditional materials due to rapid curing and wonderful bond to cement concrete, acrylic and epoxy polymer concrete have been used. Due to high mechanical properties, there are reports on the use of polymer concrete elements in machine tool, furan resin, methyl methacrylate, unsaturated polyester resin, polyurethane resins, urea formaldehyde resin, epoxy resin, and blends of polyester/styrene are usually explored as polymer concrete systems. The benefits of using polymeric resin are that it possesses long durability, high mechanical strengths, long sturdiness, and resistance to chemical attack.

Polymer-impregnated concrete is another kind of polymer concrete, in this case the hydraulic binder is completely substituted with a polymeric material. The monomer penetrates the concrete matrix to a finite depth, when it is in polymer- impregnated concrete. The mixture of conventional hydraulic cement concrete and high molecular weight polymers, known as polymer cement concrete. Generally polymer cement concrete is used as repair material.

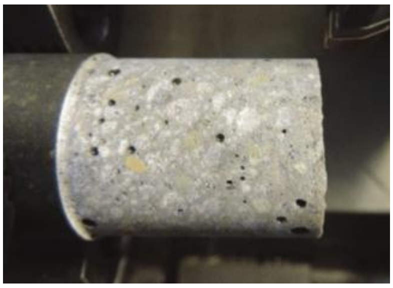

Fig 1: The view of sample made of polymer concrete

2. POLYFURFURYL ALCOHOL BASED POLYMER CONCRETE

1.1 Furfuryl alcohol

Furfuryl alcohol is an organic compound. Furfuryl alcohol containing a furan substituted with a hydroxymethyl group. It's a colorless liquid, however aged samples seem amber. It possesses a bitter taste and faint odor of burning. It's compatible and miscible with but unstable in water. It's soluble in common organic solvents. Furfuryl alcohol is formed industrially by hydrogenation of furfural, that is itself usually made from waste bio-mass like corncobs or sugar cane bagasse. As such furfuryl alcohol could also be considered a green chemical.

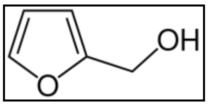

Fig 2.1: Furfuryl alcohol structure

1.2 Polyfurfuryl alcohol

Poly-FA is a liquid thermoset obtainable during a big selection of viscosities and polymerization is mediated by acid catalysts or temperature. Curing yields a tough, hard, rigid and extremely crosslinked polymer with distinctive extreme temperature properties.

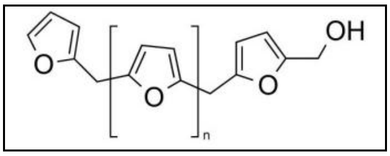

Fig 2.2: Polyfurfuryl alcohol structure

1.3 Polyfurfuryl alcohol based Concrete

From a blend of furfuryl alcohol monomer and an acidic hardener mixed with a mineral aggregate system, the polymer concrete was shaped. The furfuryl alcohol monomer was polymerized in place within the mixture to produce a extremely cross-linked resinous polymer concrete during which the mineral aggregates were dispersed or bound within the polymer binder.

Polymer concrete formed from furan polymers offered the broadest vary of chemical resistance reported and were more advantageous for manufacturing a usable concrete product as a result of the comparatively low viscosity, mixing, consolidation, ease of handling, flow and finish, and fast cure at ambient temperatures.

As a result of the advantageous raw material availability and cost performance relative to different organic binders furan based monomer have been utilised in polymer concrete. The furan polymer concretes of present invention once cured produce a extremely cross-linked resinous concrete during which the aggregate materials are dispersed inside the resin binder. The furan polymer concretes of this invention provide the broadest vary of chemical resistance over all different types of polymer concretes that are based upon totally different polymer systems or based on furan polymer systems of various aggregate varieties. Consequently, it's an object of this present invention to provide an improved concrete.

Fig 2.3: Polymer Concrete

In accordance with the aforementioned object, another object of this present invention is to provide a polymer concrete during which a furan polymer is utilized because the binder for the concrete aggregate system, water binder systems, replacing typical hydraulic cement. Another object of this invention is to provide a polymer concrete devoid of water and that is formed from the in place polymerization of furfuryl alcohol monomer mixed with an aggregate system to provide a concrete product which might be used with success for a good wide variety of functions and purposes. Specically, the polymer concrete of this invention is made from a blend of furfuryl alcohol monomer and an acidic hardener mixed with a mineral aggregate system. The furfuryl alcohol monomer is polymerized in place inside the mixture to produce a extremely cross-linked resinous polymer concrete during which the mineral aggregates are dispersed or bound inside the polymer binder. Polymer concretes formed from furan polymers provide the broadest vary of chemical resistance reported and are more advantageous for manufacturing a usable concrete product as a result of the comparatively low viscosity, consolidation, mixing, simple handling, flow and finish, fast cure at close or ambient temperatures of such concretes and since of the advantageous raw material availability and cost performance relative to different organic binders that have been utilised in polymer concretes.

Furfuryl alcohol monomer cures within the presence of most inorganic, organic and latent acid hardeners, like phosphoric acid, benzene sulfonic acid, urea nitrate, sulfuric acid and toluene sulfonic acid. Selection of an optimum catalyst system, whether or not solid or liquid, depends on several factors as well as the field conditions during which the polymer concrete is to be used. Field conditions - temperature, humidity and batch size of the polymer concrete must be considered since all of these condition are going to be an factor during which catalyst system is utilized.

3. POLMER CONCRETE AS A MATERIAL AND IT'S PROPERTIES AND OTHER PARAMETERS

3.1 The problem is that resources or raw materials are finite so after few hundred years one may not find Portland cement in abundance. Therefore an alternative is to use polymer concrete based on polyester and epoxy based thermoset resins. It's observed that the increase in the mechanical strength of both polymer cement mortar and polymer mortar with the addition of epoxy resin. This polymer concrete can be used for a wide variety of uses such as for applications in heavy industrial environments and coverings, coatings and repairs in which strength, flexibility, and chemical resistance are required. The compressive strength and flexural strength of polymer concrete are dependent upon the content of thermoset resin. However, the optimum thermosetting organic compound like resin content for a specific polymer concrete system is additionally dependent upon the character of aggregate used in the system [1].

3.2 (1) When either a polymer emulsion or a powdered polymer is mixed with cement, spherical polymer particles independently fill the interface between the cement particles, and hydrates produced after hardening crowd around the polymer particles.

(2) When powdered polymer is mixed with either cement paste or alkali solution, it disperses and displays the same behavior as in the case where an ordinary polymer emulsion is used.

(3) The reason for the increase of bending strength of PMC is explained by the action of the polymer particles

distributed in the hardened cement as reinforcing particles. The diminishing of the mean free path results in the complication of the propagation course of crack in the hardened cement. For the composite mechanism of PMC it is necessary to consider the particulate reinforced composite type.

(4) The reason why the adhesiveness of PMC to other materials is increased may be explained by the formation of a film in the interface with other materials[2].

3.3 The use of polymer resin binder, instead of cement gives stronger concrete with good chemical resistance and quick setting properties. These characteristics decide the application of this concrete at places where these characteristics are desired. Compressive strength of polymer concrete is inflated by reducing void content by exploitation small or micro filler. Amount of resin, aggregate type and amount, curing agent also as promoter play critical role within the strength properties of the polymer concrete. Concrete based on poly furfuryl alcohol resin show higher compressive strength and load bearing capacity in comparison to cement concrete. Thus in process industries and in other areas where chemical resistance, quick setting time and specific compressive strength is desired, the polymer concrete finds definite application[3].
3.4 Polymer concrete (PC) is a composite material in which the binder consists entirely of a synthetic organic polymer. It is variously known as plastic resin concrete, synthetic resin concrete or simply resin concrete. Because the use of a polymer rather than portland cement represents a substantial increase in cost. Polymers should be used only in applications in which the greater cost can be justified by low labour cost, superior properties and low energy needs throughout processing and handling. It's thus vital that architects and engineers have some information of the capabilities and limitations of PC materials so as to pick the most acceptable, appropriate and economic product for a selected and specific application[4].

3.5 Properties such as cure time flexural strength and resistance to water absorption were studied by varying the level of fly ash. It can be concluded that fly ash can be used as a fine aggregate material for partially or fully replacing ordinal river sand in polymer concrete systems. Fine aggregates in combination with fly ash and river sand showed synergism in strength behaviour and resistance to water absorption up to the level of 75% by weight of fly ash. At the higher level of fly ash, properties declined as the mix becomes unworkable. The resin binder are often improved by increasing the quantity of resin in the mix when cure time , strength and resistance to water absorption of ash filled polymer concrete using unsaturated polyester[5].

3.6 The polymer has three effects: 1) it partially obstructs the fine pore network inside of hydrates; 2) it fills the large pores; and 3) it forms membranes that encapsulate the cement grains. These effects combine to decrease permeability and hydration rate [6].

3.7 Addition of polymer in cement and aggregate act as polymer modified concrete which had very effective results as compared to that of the conventional concrete. The addition of polymer improved workability, flexural strength, tensile strength and bond strength. After addition of polymer there was dispersion effect of polymer in cement which fills the pores present in the voids. Polymer formed the layer on the cement and aggregate paste which result in the less permeability of concrete and therefore less water retention property. Because of less water retention property moisture in the concrete is reduced and thereby there is reduction in the corrosion and environmental causes to the concrete [7].

3.8 Three types of polymer resins were investigated: two types of epoxy and one type of polyester. The studied parameters included the percentage of polymer in the concrete mix three percentages were used: 9, 12 and 15%., and the reinforcement ratio. The modulus of rupture and ultimate compressive strains for PC were much higher than that of ordinary Portland cement concrete. The beams showed a very ductile behaviour and high ductility factors were obtained. The modulus of rupture for polymer concrete was observed to be 3 times higher than that of ordinary Portland cement concrete of the same ultimate compressive strength. The ultimate compressive strains for reinforced PC beams were much higher than those for ordinary concrete[8].

Applications of polymer concrete

3.9 A study was made on properties of polymer modified mortars used as repair materials. One SBR and one Acrylic based polymer have was selected for study. These polymers are added to mortar and these polymers are used as polymer modified mortars (PMMs) for various applications. Compressive strength, water permeability , bond strength and flexural strength of these PMMs were studied. SBR polymer possesses better properties than Acrylic polymer. Both have gotten better properties than unmodified cement mortar. The flexural strength and bond strength of Acrylic and SBR mortars were much above that of plain cement mortar. SBR and Acrylic mortars are more impermeable than plain cement mortar. Polymer modified mortars have higher values for flexural strength and bond strength. Bond strength of Acrylic and SBR mortars are like that of epoxy based bonding agent. Compared to plain cement mortar, Acrylic and SBR mortars showed only a small increase in compressive strength. Properties of SBR and Acrylic modified mortar improves as polymer percentage increases and cement content increases. When the polymers are added in the mixture, the workability of mortar mix improves. Hence by reducing water/cement ratio properties could also be further improved [9].

3.10 (1) The polymer concrete with polyester resin and quartz is an appropriate material for manufacturing machine tool beds with respect to damping.
(2) It has not been possible to determine if the damping characteristic of polymer concrete changes depending on the composition of the filler. Critical damping characteristics of different samples were found to be similar[10].

3.11 The exothermic reaction between the resin (Part-A) and hardener (Part-B) could generate temperatures up to 75°C which were uncomfortable to handle and difficult to work with. The addition of a filler to the resin resulted in a temperature within a comfortable working range. The mixes containing filler volumes of more than 60% were not able to produce a workable polymer matrix[11].

3.12 The precast use of polymer concrete using polyester resin based on recycled PET waste. This study has shown that PC using an unsaturated polyester resin based on recycled PET is a very feasible material for precast applications. Resins with low viscosity and good wetting properties are important since they produce workable PC with high aggregate-to-resin ratio. The material can achieve more than 80% of its final strength in one day, an important advantage in many structural applications. The material does experience significant loss in strength at high temperatures. However, despite this loss, the material remains very strong in compression and flexure when compared to regular portland cement concrete. The addition of steel reinforcement significantly increases the ultimate bending strength of the polymer concrete[12].

3.13 The effects of temperature on the mechanical properties of polymer concretes containing silicone rubber were experimentally estimated using sensors. The mixing ratio of the standard polymer concrete was 80:20 (aggregate: epoxy resin) by weight base, and 0%, 3%, and 5% of the epoxy resin were replaced by the same amount of silicone rubber to enhance the compliance of the standard polymer concrete. A small scale monitoring system with three sensors was fabricated to estimate temperature induced strains in materials[13].

Scope and origin of project

Polymer concrete is extremely much capable of replacing conventional concrete in many applications. Polyurethane as a resin isn't used currently for making resin based polymer concrete. Therefore polyurethane based polymer concrete may be a relatively newer material that has not been tested for cast concrete based applications. Polycrete is currently getting used commercially as an overlay on concrete screed, therefore is designed to meeting flooring requirements.

Epoxy is widely used material in polymer concrete but may be a costly resin compared to polyurethane. Therefore the polycrete system was used as an alternate to cast concrete applications. The compressive strength, impact resistance and flexural strength of polycrete is to be compared to that of M20, M40 and NP3 hume pipes. Effect of aggregate size on concrete is studied by replacing the fine and coarse aggregates by the micro aggregates utilized in polymer concrete. Another variation used was fiber addition. PP construction fibers were added to all the mix designs and polycrete to review their influence. Other material properties like specific gravity, water absorption, specific heat, relative density, exotherm characteristics are to be studied for polycrete. Various other applications were identified during the course of this project relying on the properties obtained from the test results.

4. PROCEDURE AND EXPERIMENTAL WORK

4. 1 The procedure for casting the polyfurfuryl alcohol (PFA) polymer concrete is as follows:

1. Take required amount of furfuryl alcohol resin and weight according to total batch weight for preparing for one test specimen.
2. Then preferred acid catalyst (p toluene sulphonic acid) is added about 8-12 % of total resin weight.
3. Simultaneously mix crushed sand and fine coarse aggregate for 3-4 min for proper mixing.
4. when initiator or acid catalyst is added into the furfuryl alcohol resin, then constantly mix the solution with rotating agitator for 3 min , when the resin color changes from yellow to red then add the aggregates and mix the resin and aggregates for 1 min and directly pour into mold.

The function of each of the ingredients added to the polymer concrete of the present invention can be characterized. The fine and coarse aggregates serve as fillers and compression strength contributors after the monomer has polymerized and they polymerized resin has hardened. The silica flour serves to give a smooth finish on top-bottom and sides, filling voids left by the fine aggregate. The polymerized furan resin, of course, serves as the binder for the aggregates and silica flour, holding the strength-giving mineral aggregates together as a monolithic structure. The catalyst serves to polymerize the furfuryl alcohol monomer to form a solid binder. Other agents may be added such as coupling agents to enhance the adherence of the resin binder to the mineral aggregates.

Composition required for Testing
Compression Test mold:
Total weight = 20% PFA resin + 80% aggregates
20% PFA resin = 90% PFA monomer +10% Sulphonic acid (initiator)
Flexural Test mould:
Total weight = 20% PFA resin + 80% aggregates
20% PFA resin = 90% PFA monomer +10% Sulphonic acid (initiator)

5. PROCEDURE FOR CASTING AND TESTING SPECIMENS

5.1 Concrete

Concrete casting carried for mix designs M20, M40 and NP3 Hume pipe.
Concrete castings varied by

1. Concrete Base formulation

Concrete base formulation casting and testing done in accordance with IS 516.

2. Concrete + PP Fibers

PP fibers addition done by immersing the PP fibers in water for few minutes, then adding it to the mixture for effective distribution.

3. Concrete (without aggregate content) + Micro aggregates

Conventional aggregates replaced by micro aggregates as weight fraction substitution.

4. Concrete (without aggregate content) + Micro aggregates +PP fibers

A workable mixture of cement, water and micro aggregates prepared. Fiber addition done after a few minutes of mixing concrete.

All mixing carried out in a mixer with maximum capacity 250g till required workablility (slump of 70-80 is obtained). After achieving the desired workability, concrete is casted into respective molds and placed on a vibrator to promote compaction and avoid air traps.

Specimens demolded after 24 hours and kept in water till the time of testing.

Specimens tested for Compressive, flexural and impact strength.

Testing carried in a standard compression testing machine and flexural testing machine.

Fig 5.1: Casted concrete compression and flexural specimens

5.2 Impact strength Test Procedure

Specimens after achieving the necessary workability, were poured into PP/Aluminum molds with dimensions 180mm*140mm*80mm.
Specimens demolded after 24 hours and immersed in water till test date(21 days from date of casting).
Specimens subjected to falling weight impact test where the weight is a rod having a hemispherical end and weighs 3.5 and 6.8 kg and is dropped from height of 1 meter.
The number of blows required to initiate first crack and cause ultimate failure was noted.
The impact energy is equal to the amount of potential energy absorbed by the sample during its course of test.
The sample was impacted maximum 20 times by 1 weight. If it showed no ultimate failure weight was increased or for maximum weight sample declared unbreakable.

Fig 5.2: Impact testing specimen with mold

5.3 Polycrete

Polycrete is available in the form of a pack containing a resin, hardner and a mixture of cement and aggregate. The resin (aqueous emulsion) is stirred to achieve homogeneity and hardner immediately added to it and the resulting mixture is stirred for 2 minutes. The solid mixture comprising of cement and micro aggregate is added to the liquid mixture and the resultant mixture is stirred till sufficient exotherm appears and viscosity is just enough to allow it to flow. The viscous mixture is then poured into respective molds and allowed to set. The specimen is demolded after 24 hours and kept in ambient air for at least 3 days (conditioning) until test date. In the following report, we have also carried out the testing for unconditioned samples. Since Polycrete contains micro aggregates, smaller size specimens are used for testing purpose. Compression, flexural and impact strength tests are the mechanical tests carried out. A variant of this is addition of fibers to polycrete. Fibers were added in the same ratio as of concrete as well as other varying ratios to find out the optimum fiber content.

Stirrer: handheld stirrer with maximum rpm of 500.

Vessel dimensions: 400mm OD with 20 mm thickness and height 140mm.

Fig 5.3 : Vessel used for batch mixing of polycrete

5.4 Other tests

5.4.1 Water retention test : A weighed specimen of polycrete was submerged in water for 3 days and the weight was recorded after taking out the sample from water.

5.4.2 Exotherm test : The enthalpy change in the sample was noted as a function of time. Polycrete sample was casted in a plastic mold/paper cup with a hollow copper rod immersed in it upto half mark.

The hollow copper tube contained a thermometer which recorded temperature as a function of time.

Temperatures were noted till it reaches a peak and then starts decreasing.

5.4.3 Specific gravity test (SP) : The weight of a polycrete specimen was found in water as well as in air. The specific gravity was obtained using formula

$SP= W2-W1/(W2-W1)-(W3-W4)$

Where,

W1= wt of container

W2= wt of container + solid in air

W3= wt of container + water + solid in water

W4= wt of Container + water

RESULTS AND OBSERVATIONS

6. Mechanical test results and their interpretation

6.1 Trial 1

Base concrete M20

Specimens casted:

Compression: 15 cubes: 150mm*150mm*150mm

Flexural: 3 beams: 150mm*150mm*700mm

Impact: 3 specimens: 140mm*180mm*80mm

Mix design:

Cement: 20.047 g

Crushed sand: 50.726 g

20mm (coarse aggregate): 70.044 g

Water: 11.026 g

Cement: FA: CA :: 1 : 2.5 : 3.49

W/c : 0.55

(Where, FA- Fine aggregate, CA- Coarse aggregate , W/C- Water-Cement ratio)

Results:

Compression:

Day of testing	Sample	Weight (kg)	Dimension (mm^3)	Load (kN)	Strength (Mpa)	Average strength (Mpa)
Day 7	1	8.879	149.5*151*151.5	566.1	25.07	26.48
	2	8.962	150.1*149.9*150.7	662.5	29.44	
	3	9.043	151.5*151.3*150.1	571.6	24.93	
	1	9.081	150.6*150.1*150.9	756.6	33.47	

Day 14	2	9.030	150.7*150.2*151	887.1	39.19	36.25
	3	8.879	152*151.5*150.7	831.1	36.08	
Day 21	1	8.918	150.3*150.5*150.7	896.4	39.62	40.76
	2	8.973	149.5*150.1*150.4	975.6	43.47	
	3	8.980	150.6*151.3*151.3	893.6	39.21	

Table 6.1 a

Fig.6.1(a): compression specimen moulds

Flexural:

Day of testing	Sample	Dimension (mm^3)	Load (kN)	Strength (Mpa)	Average strength (Mpa)
Day 21	1	600*150*150	14.040	2.496	2.5
	2	600*150*150	13.980	2.48	
	3	600*150*150	14.100	2.53	

Table 6.1 b

Fig.6.1(b): Flexural specimen Mould

Impact:

Day of testing	Sample	Dimensions (mm^3)	Weight of hammer (kg)	No. of blows (First crack)	No. of blows (U F)	Impact energy (J)	IE/ Thickness (mm)
Day 21	1	179.25*139.35*80.09	6.8	2	3	200.12	2.5
	2	179.67*139.28*80.19	3.5	No Crack			
			6.8		6	1087	13.55
	3	179.28*139.67*79.85	6.8	2	4	266.8	3.34

Table 6.1 c

Observations and conclusion:

The compressive strength of concrete increased with longer cure periods as expected.

The specimens were cured under water even then there is not much difference in weights between the samples tested on first and 21st day. Therefore curing under water efficient as unhydrated cement particles react with water completely till the 21st day to give maximum strength. After the 21st day, not much increase in strength is expected. Impact strength results were very discrete i.e. one sample did not break. The reasons could be improper casting of sample or can be attributed to anisotropy of material.

6.2 Trial 2

Base concrete M20+Recron 3s

Specimens casted:

Compression: 3 cubes: 150mm*150mm*150mm
Flexural: 3 beams: 150mm*150mm*700mm
Impact: 3 specimens: 140mm*180mm*80mm

Mix design:

Cement: 5.567 g
Crushed sand: 13.95 g
20mm (coarse aggregate): 19.28 g
Water: 3.06 g
Fibers: 0.010g
Cement: FA: CA :: 1 : 2.5 : 3.49

Result:

Compression:

Day of testing	Sample	Weight (kg)	Dimension (mm^3)	Load (kN)	Strength (Mpa)	Average strength (Mpa)
Day 21	1	8.837	150.4*150.1*150.6	847.5	37.54	37.61
	2	8.871	150.2*150.3*150.8	835.6	37.01	
	3	8.861	150.9*151.1*150.1	811.5	35.60	

Table 6.2 a

Flexural:

Day of testing	Sample	Dimension (mm^3)	Load (kN)	Strength (Mpa)	Average strength (Mpa)
Day 21	1	600*150*150	16.2	2.88	2.82
	2	600*150*150	13.68	2.43	
	3	600*150*150	17.82	3.167	

Table 6.2 b

Impact:

Day of testing	Sample	Dimensions (mm^3)	Weight of hammer (kg)	No. of blows (First crack)	No. of blows (U F)	Impact energy (J)	IE/ Thickness (mm)
Day 21	1	179.34*139.86*80.33	6.8	2	3	200.124	2.49
	2	179.63*139.37*80.07	3.5	15	16	548.8	6.85
	3	179.49*139.56*80.19	3.5	6	8	274.4	3.42

Table 6.2 c

Observation:

The compressive strength of M20 with fibers was lesser than that of M20.Since the fiber ratio was used according to the ratio recommended by fiber manufacturer, fiber content is not the reason for loss in strength. Also since PP fibers are hydrophobic, there is no reason for the fibers to hinder the cement hydration reaction resulting in loss of strength. Improper dispersion and distribution of fibers could be one of the reasons for lowering the compressive strength.

Addition of fibers has increased the flexural strength of M20 due to it causing a reduction in crack generation/propagation. Since addition of fibers increases the TS of specimen, flexural strength indirectly increases.

6.3 Trail 3

Base concrete M20+ micro aggregate (taken from polycrete filler set excluding cement)

Specimens casted:

Compression: 15 cubes: 50mm*50mm*50mm
Flexural: 3 beams
Impact: 3 specimens: 140mm*180mm*80mm

Mix design:

Cement: 3.242g
Micro aggregates (MA): 19.887 g
Water: 1.780+2.500 g

Result:

Compression:

Day of testing	Sample	Weight (g)	Dimension (mm^3)	Load (kN)	Strength (Mpa)	Average strength (Mpa)
Day 7	1	238.5	50.36*50.22*49.49	9.2	3.63	4.22
	2	244.5	50.32*50.55*49.63	12.4	4.87	
	3	244.5	50.61*50.24*50.86	10.6	4.16	
Day 14	1	262.5	50.63*50.91*50.64	11.6	4.5	4.55
	2	259	50.64*50.27*50.35	12	4.71	
	3	259	50.1*50.24*50.06	11.2	4.44	
Day 21	1	258	49.7*49.51*49.33	17.7	7.19	5.72
	2	257	49.80*49.41*49.98	14.3	5.81	
	3	258	50.07*50.08*49.98	10.5	4.18	

Table 6.3 a

Flexural:

Day of testing	Sample	Dimension (mm^3)	Load (kN)	Strength (Mpa)	Average strength (Mpa)
Day 21	1	90*25*25	4.410	25.4	23.61
	2	90*25*25	3.814	21.9	
	3	90*25*25	4.089	23.54	

Table 6.3 b

Impact:

Day of testing	Sample	Dimensions (mm^3)	Weight of hammer (kg)	No. of blows (First crack)	No. of blows (U F)	Impact energy (J)	IE/ Thickness (mm)
Day 21	1	179.66*139.54*80.06	6.8		2	133.28	1.66
	2	179.53*139.24*80.24	3.5	4	5	171.5	2.14
	3	178.97*139.77*80.18	3.5	3	4	137.34	1.71

Table 6.3 c

Observations :

Extra water than actual mix design was needed for this trial to maintain the workability of mixture. The micro aggregates are also chemically cementitious materials. Therefore there was just paste formation. The low bulk density and high surface area of micro aggregates could be on reason for higher water consumption. Due to the high surface area of micro aggregates, the amount of cement paste required was lesser than to completely bind the aggregates. This is the reason for more requirement of water resulting in a dilute cement paste formation thereby decreasing the adhesive content of cement paste. Theoretically 23% of water is required to completely hydrate the cement and another 15% is required to fill up the gel pores of cement gel formed. Therefore ideally one should not use more than 38% water for concrete mixing, whereas here the W/C ratio was greater than 1.On analyzing the specimens, they showed brittle failure. There was no bonding between micro aggregates and the cement. Micro aggregates could be scraped off with fingers from the specimen.

6.4 Trial 4
Base concrete M20 + micro aggregates + fibers
Specimens casted:
Compression: 3 cubes: 150mm*150mm*150mm
Flexural: 3 beams : 150mm*150mm*700mm
Impact: 3 specimens: 140mm*180mm*80mm
Mix design:
Cement: 2.830g
Micro aggregates : 16.900 g
Water: 1.557+1.500 g
Fibers: 6 g
Result:
Compression:

Day of testing	Sample	Weight (g)	Dimension (mm^3)	Load (kN)	Strength (Mpa)	Average strength (Mpa)
Day 21	1	254	50.21*50.01*51.31	19.1	7.6	9.16
	2	249	50.51*49.13*51.81	24.0	9.67	
	3	247	50.40*49.1*51.55	25.3	10.22	

Table 6.4 a

Flexural:

Day of testing	Sample	Dimension (mm^3)	Load (kN)	Strength (Mpa)	Average strength (Mpa)
Day 21	1	90*25*25	5.660	32.6	29.38
	2	90*25*25	4.902	28.23	
	3	90*25*25	5.144	29.62	
	4	90*25*25	4.700	27.06	

Table 6.4 b

Impact:

Day of testing	Sample	Dimensions (mm^3)	Weight of hammer (kg)	No. of blows (First crack)	No. of blows (U F)	Impact energy (J)	IE/ Thickness (mm)
Day 21	1	179.87*139.82*80.04	6.8	2	3	199.92	2.5
	2	179.55*139.60*80.21	3.5	7	9	308.7	3.8
	3	179.79*139.82*80.01	3.5		16	548.8	6.86

Table 6.4 c

Observation:

Since there is increase in compression strength (CS) as compared to trial 3, we can conclude that fiber amount added was below the threshold content leading to increase in strength. Impact strength of this system increased owing to addition of fibers when compared to trial 3. Fibers stop the crack propagation and a good bond between the fibers and concrete reduce the brittleness failure tendency of concrete. From the results of flexural strength, we can see that micro aggregates act as micro sized fillers and along with fibers they help in reduction in crack propagation.

6.5 Trial 5
Base concrete M40
Specimens casted:
Compression: 15 cubes: 150mm*150mm*150mm
Flexural: 3 beams : 150mm*150mm*700mm
Impact: 3 specimens: 140mm*180mm*80mm
Mix design:
Cement: 26.291g

Crushed sand: 49.396 g
20mm (coarse aggregate): 74.128g
Water: 10.516
Cement: FA: CA :: 1 : 1.87 : 2.819

Result:

Compression:

Day of testing	Sample	Weight (kg)	Dimension (mm³)	Load (kN)	Strength (Mpa)	Average strength (Mpa)
Day 7	1	9.058	150.09*150.23*150.09	898.9	39.86	42.90
	2	8.865	150.09*148.5*150.54	1006	45.13	
	3	9.060	152.0*151.09*151.21	1004.2	43.72	
Day 14	1	8.928	150.5*150.1*150.9	1117.5	49.46	49
	2	9.146	150.6*150.4*150.8	1157.5	51.1	
	3	9.022	151.0*150.7*150.6	1056.2	46.41	
Day 21	1	9.033	151.3*150.7*151.4	1158.9	50.82	54.18
	2	9.072	150.5*150.7*150.9	1302.4	57.42	
	3	9.076	151.3*151.5*150.7	1245.3	54.32	

Table 6.5 a

Flexural:

Day of testing	Sample	Dimension (mm³)	Load (kN)	Strength (Mpa)	Average strength (Mpa)
Day 21	1	600*150*150	34.560	6.144	5.8
	2	600*150*150	34.680	6.16	
	3	600*150*150	28.320	5.03	

Table 6.5 b

Impact:

Day of testing	Sample	Dimensions (mm³)	Weight of hammer (kg)	No. of blows (First crack)	No. of blows (U F)	Impact energy (J)	IE/ Thickness (mm)
Day 21	1	179.86*139.45*80.35	6.8	No Crack	2	133.28	1.66
	2	179.64*139.25*80.47	6.8	No Crack	2	133.28	1.66
	3	179.70*139.27*80.21	3.5	No Crack			
			6.8		No Failure		

Table 6.5 c

Observation:

An expected increase in CS of M40 is observed. Owing to the mix design, The CS of M40 is greater than that of Trial 1. The impact specimen was not breakable with 3.5 kg load but broke with 2 impacts of 6.8 kg. Therefore it can sustain a large number of blows of lesser weight than sustaining heavier blows. Day 14 compressive strength is greater than Day 7 strength. This may be attributed to the homogeneity of casting. The greater flexural and CS as compared to M20 may be due to the lesser FA/CA ratio thereby reducing the surface area and cement paste requirement for binding. The increased cement paste content leads to a better interfacial adhesion.

6.6 Trail 6

Base concrete M40+ fibers

Specimens casted:

Compression: 3 cubes: 150mm*150mm*150mm
Flexural: 3 beams: 150mm*150mm*700mm
Impact: 3 specimens: 140mm*180mm*80mm

Mix design:
Cement: 9.971g
Crushed sand: 18.556 g
20mm (coarse aggregate): 27.882g
Water: 3.990+0.300 g

Result:
Compression:

Day of testing	Sample	Weight (kg)	Dimension (mm^3)	Load (kN)	Strength (Mpa)	Average strength (Mpa)
Day 28	1	9.0	150.6*150.1*150.8	1365.9	60.42	54.71
	2	8.957	150.5*150.3*149.7	1226.3	54.21	
	3	9.112	149.9*150.3*150.4	1115.5	49.51	

Table 6.6 a

Flexural:

Day of testing	Sample	Dimension (mm^3)	Load (kN)	Strength (Mpa)	Average strength (Mpa)
Day 28	1	600*150*150	28.26	5.024	5.806
	2	600*150*150	32.34	5.749	
	3	600*150*150	37.38	6.645	

Table 6.6 b

Impact:

Day of testing	Sample	Dimensions (mm^3)	Weight of hammer (kg)	No. of blows (First crack)	No. of blows (U F)	Impact energy (J)	IE/ Thickness (mm)
Day 28	1	179.36*139.82*80.12	6.8	3	5	333.2	4.15
	2	179.55*139.14*80.20	6.8	6	7	466.48	5.83
	3	179.32*139.41*80.09	6.8	5	6	399.84	4.998

Table 6.6 c

Observations:
Almost same compressive strength observed as of trial 5 which proves the fact that PP fiber addition contributes negligibly to the compressive strength of concrete as in literature. As expected addition of fibers lead to increase in impact strength of concrete.

6.7 Trial 7
Base concrete M40+micro aggregates
Specimens casted:
Compression: 15 cubes: 50mm*50mm*50mm
Flexural: 3 beams: 150mm*150mm*700mm
Impact: 3 specimens: 140mm*180mm*80mm
Mix design:
Cement: 4.146g
MA: 19.452 g
Water: 1.656 + 3 (excess) g
Result:
Compression:

Day of testing	Sample	Weight (g)	Dimension (mm^3)	Load (kN)	Strength (Mpa)	Average strength (Mpa)
Day 7	1	252.5	50.06*50.92*52.12	14.3	5.6	6.51
	2	262.5	50.04*51.59*49.89	17.7	6.85	
	3	264.0	50.24*50.12*50.14	17.9	7.1	

Day 14	1	263.5	49.58*50.66*49.90	30.7	12.22	12.58
	2	268	50.52*49.86*50.08	30.3	12.02	
	3	272.5	50.30*49.85*51.75	33.9	13.52	
Day 21	1	259.5	49.50*50.30*49.70	33.4	13.4	13.44
	2	268.5	49.42*49.05*49.91	35.2	14.52	
	3	263	50.40*49.33*49.42	30.9	12.42	

Table 6.7 a

Flexural:

Day of testing	Sample	Dimension (mm³)	Load (kN)	Strength (Mpa)	Average strength (Mpa)
Day 21	1	90*25*25	3.731	21.5	27.03
	2	90*25*25	4.738	27.28	
	3	90*25*25	4.883	28.12	
	4	90*25*25	5.425	31.24	

Table 6.7 b

Impact:

Day of testing	Sample	Dimensions (mm³)	Weight of hammer (kg)	No. of blows (First crack)	No. of blows (U F)	Impact energy (J)	IE/ Thickness (mm)
Day 21	1	179.16*139.67*80.07	6.8	1	2	133.2	1.665
	2	179.28*139.28*79.81	3.5	6	8	274.4	3.43
	3	179.81*139.20*80.19	3.5	2	4	137.2	1.71

Table 6.7 c

Observations:

The large surface area to volume ratio of micro aggregates results in them capable of absorbing more impact energy as compared to trial 5

6.8 Trail 8

Base concrete M40+ micro aggregates + Fibers

Specimens casted:

Compression: 3 cubes: 50mm*50mm*50mm
Flexural: 3 beams: 150mm*150mm*700mm
Impact: 3 specimens: 140mm*180mm*80mm

Mix design:

Cement: 3.52g
MA: 16.359 g
Water: 1.406+2(excess)g
Fibers: 7g

Result:

Compression:

Day of testing	Sample	Weight (g)	Dimension (mm³)	Load (kN)	Strength (Mpa)	Average strength (Mpa)
Day 21	1	249	50.55*50.83*50.80	20.8	8.09	8.27
	2	263	49.60*50.00*50.74	21.8	8.79	
	3	263	50.63*51.84*49.40	20.8	7.92	

Table 6.8 a

Flexural:

Day of testing	Sample	Dimension (mm³)	Load (kN)	Strength (Mpa)	Average strength (Mpa)
	1	90*25*25	5.537	31.88	

Day 21	2	90*25*25	5.010	28.85	28.28
	3	90*25*25	3.833	22.06	
	4	90*25*25	5.267	30.33	

Table 6.8 b

Impact:

Day of testing	Sample	Dimensions (mm³)	Weight of hammer (kg)	No. of blows (First crack)	No. of blows (U F)	Impact energy (J)	IE/ Thickness (mm)
Day 21	1	179.35*139.26*80.14	6.8		2	133.28	1.66
	2	179.47*139.17*80.02	3.5	8	9	308.7	3.85
	3	179.24*139.11*80.11	3.5	10	11	377.3	4.71

Table 6.8 c

6.9 Trial 9

Base concrete NP3

Specimens casted:

Compression: 15 cubes: 150mm*150mm*150mm

Flexural: 3 beams: 150mm*150mm*700mm

Impact: 3 specimens: 140mm*180mm*80mm

Mix design:

Cement: 27.648g

Crushed sand: 56.64 g

20mm (coarse aggregate): 61.210 g

Water: 11.059 g

Plasticizer: 331.776 g (BASF 850i)

Cement: FA: CA :: 1 : 2.04: 2.21

W/c: 0.4

Result:

Compression:

Day of testing	Sample	Weight (kg)	Dimension (mm³)	Load (kN)	Strength (Mpa)	Average strength (Mpa)
Day 7	1	8.938	150.1*150.3*150.6	960	42.55	39.66
	2	8.937	150.4*150.7*150.1	835.2	36.8	
	3	8.897	150.9*151.5*150.7	906.1	39.63	
Day 14	1	8.856	150.9*151*149.8	1148.1	50.38	45.8
	2	8.984	149.7*150.5*150.4	998.3	44.38	
	3	8.951	150.6*150.8*151.3	969.8	42.7	
Day 21	1	8.886	150.9*151.4*150.7	1312.9	57.46	54.91
	2	8.879	151.3*150.9*150.8	1275.1	55.84	
	3	8.878	150.1*150.4*150.6	1161.2	51.43	

Table 6.9 a

Flexural:

Day of testing	Sample	Dimension (mm³)	Load (kN)	Strength (Mpa)	Average strength (Mpa)
Day 21	1	600*150*150	19.020	3.38	3.11
	2	600*150*150	18.66	3.317	
	3	600*150*150	14.88	2.645	

Table 6.9 b

Impact:

Day of testing	Sample	Dimensions (mm^3)	Weight of hammer (kg)	No. of blows (First crack)	No. of blows (U F)	Impact energy (J)	IE/ Thickness (mm)
Day 21	1	178.87*139.88*80.25	6.8	1	2	133.28	1.66
	2	179.55*139.74*80.64	3.5	No Crack			
			6.8		5	1019.2	12.74
	3	179.23*139.14*80.12	6.8	3	4	266.56	3.332

Table 6.9 c

Observations:
As expected, NP3 has a better compressive, flexural and impact strength than both M20 and M40.This is due to a lower W/C ratio, and higher FA/CA ratio.

Fig 6.9: Ultimately failed specimen

6.10 Trial 10
Base concrete NP3+ fibers
Specimens casted:
Compression: 3 cubes: 150mm*150mm*150mm
Flexural: 3 beams: 150mm*150mm*700mm
Impact: 3 specimens: 140mm*180mm*80mm
Mix design:
Cement: 10.944g
Crushed sand: 22.423 g
20mm (coarse aggregate): 24.271 g
Water: 4.3776 g
Plasticizer: 131.328g (BASF 850i)

Result:
Compression:

Day of testing	Sample	Weight (kg)	Dimension (mm^3)	Load (kN)	Strength (Mpa)	Average strength (Mpa)
Day 21	1	9.17	150.7*150.6*151.4	1043.0	45.95	51.09
	2	8.989	150.5*150.1*150.8	1183.9	52.40	
	3	9.059	150.4*151.0*150.3	1247.7	54.94	

Table 6.10 a

Flexural:

Day of testing	Sample	Dimension (mm^3)	Load (kN)	Strength (Mpa)	Average strength (Mpa)
Day 21	1	600*150*150	11.300	2	2.372
	2	600*150*150	13.800	2.45	
	3	600*150*150	14.940	2.656	

Table 6.10 b

Impact:

Day of testing	Sample	Dimensions (mm³)	Weight of hammer (kg)	No. of blows (First crack)	No. of blows (U F)	Impact energy (J)	IE/ Thickness (mm)
Day 21	1	179.18*139.34*80.25	6.8	6	7	466.48	5.83
	2	179.82*139.61*80.10	6.8		2	133.28	1.6
	3	179.22*138.89*19.71	6.8	7	8	533.12	6.6

Table 6.10 c

6.11 Trail 11
Base concrete NP3+ micro aggregates
Specimens casted:
Compression: 15 cubes: 50mm*50mm*50mm (To be tested at 7, 14, 21 days)
Flexural: 3 beams: 150mm*150mm*700mm (to be tested at 21st day)
Impact: 3 specimens: 140mm*180mm*80mm (to be tested at 21st day)
Mix design:
Cement: 4.545g
micro aggregates: 18.877 g
Water: 1.818 +2.850 g

Result:
Compression:

Day of testing	Sample	Weight (g)	Dimension (mm³)	Load (kN)	Strength (Mpa)	Average strength (Mpa)
Day 7	1	275	50.34*50.41*50.24	30.6	12.05	10.81
	2	265	49.74*50.69*49.43	22.2	8.8	
	3	274.5	50.75*50.31*49.86	29.6	11.59	
Day 14	1	269	49.7*49.4*50.51	40.7	16.57	15.38
	2	269	49.3*49.71*50.62	39.3	16.03	
	3	266	50.63*49.70*49.33	34.1	13.55	
Day 21	1	270	50.2*50.1*50.9	37.3	14.8	19.01
	2	261	48.8*49.6*48.8	58	23.96	
	3	261.5	50.4*50.7*49.9	46.7	18.27	

Table 6.11 a

Flexural:

Day of testing	Sample	Dimension (mm³)	Load (kN)	Strength (Mpa)	Average strength (Mpa)
Day 21	1	90*25*25	5.910	34.04	37.18
	2	90*25*25	7.232	41.65	
	3	90*25*25	6.075	34.98	
	4	90*25*25	6.710	38.06	

Table 6.11 b

Impact:

Day of testing	Sample	Dimensions (mm³)	Weight of hammer (kg)	No. of blows (First crack)	No. of blows (U F)	Impact energy (J)	IE/ Thickness (mm)
	1	179.68*139.52*80.3	6.8	1		66.64	0.88

Day 21	2	179.52*139.58*80.2	6.8	4		266.56	3.32
	3	179.35*139.64*80.2	3.5	No Crack			
			6.8		3	274	3.425

Table 6.11 c

6.12 Trial 12
Base concrete NP3+ fibers+ micro aggregates
Specimens casted:
Compression: 3 cubes: 50mm*50mm*50mm
Flexural: 3 beams: 150mm*150mm*700mm
Impact: 3 specimens: 140mm*180mm*80mm
Mix design:
Cement: 2.902g
micro aggregates: 12.062 g
Water: 1.161+1.80 g
Fiber: 5 g
Plasticizer: 34.824g (BASF 850i)

Result:
Compression:

Day of testing	Sample	Weight (g)	Dimension (mm^3)	Load (kN)	Strength (Mpa)	Average strength (Mpa)
Day 21	1	252	49.99*50.48*50.42	37.2	14.74	15.2
	2	254	48.62*50.51*50.77	37.5	15.2	
	3	254	50.54*50.62*50.61	41	16.02	

Table 6.12 a

Flexural:

Day of testing	Sample	Dimension (mm^3)	Load (kN)	Strength (Mpa)	Average strength (Mpa)
Day 21	1	90*25*25	5.38	30.98	32.69
	2	90*25*25	5.07	29.2	
	3	90*25*25	5.76	33.17	
	4	90*25*25	6.5	37.44	

Table 6.12 b

Impact:

Day of testing	Sample	Dimensions (mm^3)	Weight of hammer (kg)	No. of blows (First crack)	No. of blows (U F)	Impact energy (J)	IE/ Thickness (mm)
Day 21	1	179.2*139.6*80.1	6.8		1	66.64	0.8
	2	179.3*139.5*80.2	3.5	No Crack			
			6.8		3	199.2	2.5
	3	179.8*139*7*80.4	6.8	2	3	199.2	2.5

Table 6.12 c

7. POLYCRETE

7.1 Trial 1 (unconditioned samples)
Specimens casted:
12 cubes: 50mm*50mm*50mm (tested at 1, 3 and 21 days after casting of samples)
Proportion used:
Resin: 10 g

Hardener: 10 g
Aggregates: 40.6 g

Result:
Compression:

Day of testing	Sample	Weight (g)	Dimension (mm^3)	Load (kN)	Strength (Mpa)	Average strength (Mpa)
Day 1	1	230	50.21*50.14*50.27	62.1	24.667	24.554
	2	228	50.04*50.78*50.01	61.8	24.32	
	3	229	49.9*49.7*49.96	61.2	24.677	
Day 3	1	228	50.6*50.57*50.56	70.4	27.512	27.864
	2	230	50.71*50.61*50.61	43.4	28.6	
	3	225	50.62*50.70*50.65	70.5	27.47	
Day 21	1	222.5	49.42*50.08*50.08	89.3	36.08	35.36
	2	223	50.27*49.82*49.61	84.3	34.08	
	3	232	48.76*49.74*49.67	87.1	35.91	

Table 7.1

Observation:
Not much variance between strength values on a particular day of testing. This indicates more homogeneity of material over concrete. Water absorption of samples found to be 0.Since material was sticking to the mould, silicone oil was used as lubricant. Result: Failed trial. Material sticking to mold. Butter paper was used to cast 1 specimen. Result: Butter paper tore off. WOHP sheets were stuck with the help of grease to the mold. Result: Specimen easy to demold.

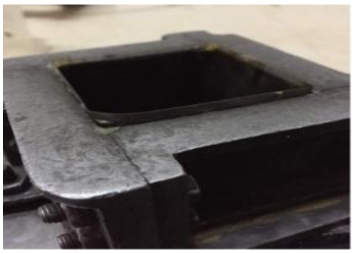

Fig7.1: Mold for casting microconcrete specimens

7.2 Trial 2 (conditioned samples)
Specimens casted:
12 cubes: 50mm*50mm*50mm (tested at 4, 7, 21 days after casting of samples)
8 beams : 90*25*25 (tested at 7,21 day)
Proportion used:
Resin: 10g
Hardener: 10g
Aggregates: 40.6 g

Result:
Compression:

Day of testing	Sample	Weight (g)	Dimension (mm^3)	Load (kN)	Strength (Mpa)	Average strength (Mpa)
Day 4	1	200	49.03*49.01*46.54	53.2	22.14	21.43
	2	208	49.85*49.37*48.03	53.1	21.57	
	3	204.5	49.42*49.25*49	50.1	20.58	
	1	211	49.92*49.09*49.14	61.5	25.09	

Day 7	2	218	49.21*49.17*51.25	59.2	24.46	24.91
	3	220	49.35*49.44*50.98	61.5	25.20	
Day 21	1	219.5	49.49*49.34*50.55	70.5	28.87	28.45
	2	209	50.24*49.00*49.11	70.3	28.55	
	3	221.5	49.78*49.31*50.51	68.6	27.95	

Table 7.2 a

Flexural:

Day of testing	Sample	Dimension (mm³)	Load (kN)	Strength (Mpa)	Average strength (Mpa)
Day 7	1	90*25*25	15.84	91.23	88.35
	2	90*25*25	15.21	87.6	
	3	90*25*25	14.90	85.8	
	4	90*25*25	15.42	88.8	
Day 21	1	90*25*25	15.53	89.4	88.83
	2	90*25*25	16.11	92.8	
	3	90*25*25	15.225	87.67	
	4	90*25*25	14.840	85.46	

Table 7.2 b

Impact:

Day of testing	Sample	Dimensions (mm³)	Weight of hammer (kg)	No. of blows (First crack)	No. of blows (U F)	Impact energy (J)	IE/ Thickness (mm)
Day 21	1	179.95*139.87*80.2	6.8	10	20	1332.8	16.66
	2	179.6*139.7*80.0	6.8		NB		
	3	179.24*139.8*80.0	6.8		NB		

Table 7.2 c

Observations:

The strength values obtained for specimens casted for trial 2 were lower than that for specimens casted for trial 1 about 1 month earlier. This can be attributed to the differences in mixing equipment, mixing vessel, quantity of mixing. During trial 1, 12 cubes were casted at a time where as during trial 2, 3 cubes were casted in sets of 4. Very high speed stirrer was used for casting trial 2 as compared to trial 1 which was casted using a much slow stirrer. During casting of both the trials, the proportions of resin hardener and aggregates were kept the same.

Fig 7.2: Stirrer and vessel used for large batch mixing of polycrete

The extremely high flexure strength of polycrete can be attributed to the use of micro sized fillers and the adhesive strength of resin and hardner which makes it better in tension than conventional concrete. Polycrete is a very resilient material. It was impossible to break it with impact loads of 3.5 kg and lesser. It was capable of sustaining about 25 blows of 6.8 kg load without any separation of failed specimen observed. The hammer bounced off the specimen surface after its impact. This indicates higher elasticity of material.

7.3 Trial 3 (samples with fibers added)
Specimens casted:
12 cubes: 50mm*50mm*50mm (tested at 4, 7 and 21 days after casting of samples)
8 beams:((tested at 7, 21 days)
Proportion used:
Resin: 10 g
Hardener: 10 g
Aggregates: 40.6 g
Fibers: 2.484 g

Result:
Compression:

Day of testing	Sample	Weight (g)	Dimension (mm^3)	Load (kN)	Strength (Mpa)	Average strength (Mpa)
Day 4	1	219.5	50.02*49.19*51.06	60.1	24.42	23.62
	2	217	49.59*49.89*51.43	58.6	23.68	
	3	216	50.12*49.88*50.19	56.9	22.76	
Day 7	1	226.5	49.96*50.83*49.14	68.6	27.01	26.67
	2	217.5	49.40*50.46*49.94	68.6	27.52	
	3	219	50.34*49.96*49.09	64.1	25.48	
Day 21	1	220	49.62*49.27*52.28	69	28.22	27.65
	2	217	48.85*49.88*51.26	65.3	26.8	
	3	214	49.24*49.50*50.27	68.1	27.93	

Table 7.3 a

Flexural:

Day of testing	Sample	Dimension (mm^3)	Load (kN)	Strength (Mpa)	Average strength (Mpa)
Day 7	1	90*25*25	16.649	95.89	88.05
	2	90*25*25	15.33	88.26	
	3	90*25*25	15.036	86.6	
	4	90*25*25	14.14	81.467	
Day 21	1	90*25*25	16.52	95.13	91.33
	2	90*25*25	15.685	90.33	
	3	90*25*25	15.23	87.72	
	4	90*25*25	16	92.16	

Table 7.3 b

Impact:

Day of testing	Sample	Dimensions (mm^3)	Weight of hammer (kg)	No. of blows (First crack)	No. of blows (U F)	Impact energy (J)	IE/ Thickness (mm)
Day 21	1	179.87*139.62*80.1	6.8		NB		
	2	179.6*139.7*80.2	6.8		NB		
	3	179.4*139.8*80.2	6.8		NB		

Table 7.3 c

Observation:
On addition of fibers the flexural strength of polycrete specimens has increased with increase in curing period. The specimen was impossible to break with 20 blows of 6.8 kg hammer and the hammer bounced on impact with specimen surface.

8. OTHER TESTS

8.1 Water retention test
Initial weight of specimen=224 g
Weight of specimen after placing it in water for 3 days=224 g
Water absorption of polycrete= 0

8.2 Exotherm characteristics
The experiment was carried out in a PP container having dimensions 180*140*80 mm with the thermometer assembly dipped halfway.

Time (min)	Temperature (^{0}c)
0	36
1.20	37
1.30	38
2.40	39
5.50	40
7.20	41
9.00	42
11.10	43
13.10	44
15.35	45
18.10	46
21.05	47
24.40	48
26.20	49
30.10	50
31	49
32.50	48
33.10	47
34.10	46

Table 8.2

Peak temperature observed = 50 ^{0}C
Time till exotherm increases=30.10 min after which heat released in surroundings is responsible for the curing of material i.e. curing takes place as a result of hardner and heat released.

8.3 Specific gravity
The specific gravity formula:
SP= W2-W1/(W2-W1)-(W3-W4)
W1=77.5, W2=278.5, W3=1631.5, W4=1430.5 and therefore the specific gravity comes out to be 1.

CONCLUSIONS

- The current formulation of polycrete can suit all concrete applications where mix design M20 is used.
- The order of 21 days Compressive strength of NP3,M40,M20 and Polycrete increases.
- The advantage of polycrete is that it can reach its maximum compressive strength within 7 days after which the compressive strength increases gradually.
- Replacement by micro aggregates does not yield an increase in compressive strength which is not expected. The mix design for concrete with micro aggregates must be changed to yield optimum results. The micro

aggregate content should be reduced drastically to maintain the workability of mixture.

- Addition of fibers contributes to very little on CS on concrete. In some cases fiber addition has resulted in decrease of compressive strength.
- Polycrete specimens give a very high flexural strength when compared to any of concrete mix designs.
- Concrete under impact loading undergoes a brittle failure and has very low impact strength values.
- On the other hand polycrete is a very tough material and difficult to break under impact loading.
- The addition of fibers further contributes to the impact strength of concrete as well as polycrete, reducing the crack initiation/propagation.
- Polycrete under impact loading does not shatter unlike concrete thus proving its vulnerability in earthquake situations.
- The ease of mixing, casting polycrete and its quick setting time coupled with high early strength can lead to its use as a repair material.
- Since its water retention is nil, it can be used as a waterproofing material and unlike concrete will not lead to rusting of steel reinforcements. Thus it can be used as a protective covering for steel rods and also contribute to compressive strength if used as a core sheath type coulmns.
- Its very high impact strength can be further modified and used as impact barriers on highways and airport runways.
- By further modifying the organic components and ratios we can enhance its compressive strength thus making it suitable for cast concrete applications.

Since polycrete is a lighter material than concrete significant weight savings can be achieved by reducing the thicknesses, thus leading to economic savings and less waste generation.

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